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THE INFLUENCE OF THE ENVIRONMENT ON THE MILLING AND BAKING QUALITIES OF WHEAT IN INDIA

No. I. THE EXPERIMENTS OF 1907-08 AND 1908-09

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PREFACE.

THE experiments described in the present paper have arisen from some preliminary trials with Muzaffarnagar white, made at Púsa, Muzaffarnagar and Lyallpur in 1907. Since that time they have been considerably extended, and now embrace ten stations and four very different classes of wheat. In addition, a large amount of other work on the influence of the environment on quality is being conducted in the Botanical areas at Púsa and Cawnpore.

We desire to take this opportunity of expressing our indebtedness to several officers of the Indian Agricultural Department for their valuable co-operation in the conduct of this work. For facilities at Dumraon and Bankipore we are indebted to Mr. F. Smith, B.Sc., Deputy Director of Agriculture, Bengal; Mr. B. C. Burt, B.Sc., and Dr. Parr, the Deputy Directors of Agriculture of the United Provinces have assisted us at Orai and Aligarh respectively. At Meerut, Babu Jugannath Pershad was good enough to give us all facilities on his farm. Mr. Mahomed Hadi, M.R.A.C., has kindly placed the resources of the Partabgarh Experiment Station at our disposal while at Lyallpur, Messrs. W. Roberts, B.Sc., and H. A. Corbin, B.Sc., have been good enough to assist in the work. During the present year, Mr. G. Evans, B.A., Deputy Director of Agriculture of the Central Provinces, has afforded us facilities at Hoshangabad in the Narbada Valley.

We are indebted to Dr. J. W. Leather, Imperial Agricultural Chemist, for a large number of nitrogen determinations.

In the milling and baking aspect of the subject we have been fortunate enough to secure the invaluable assistance of Mr. A. E. Humphries, formerly President of the National Association of British and Irish Millers and a well-known authority on these questions.

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CAWNPORE,
December 18th, 1909.

CONTENTS.

		Page.
I.	Introduction	191
II.	The Indian Problem	197
III.	The Results obtained in 1908 and 1909	201
	A. Muzaffarnagar white	201
	B. Punjab Wheats grown at Lyallpur and Cawnpore ...	215
IV.	The Experiments now in progress	219

THE INFLUENCE OF THE ENVIRONMENT ON THE MILLING AND BAKING QUALITIES OF WHEAT IN INDIA.

No. 1. The Experiments of 1907-08 and 1908-09.

I. Introduction.

The question of the effect of environment on the quality of wheat is of the greatest importance from several points of view. Not only does it affect the question of seed distribution and the introduction of new varieties, but it is also of vital interest to the breeder. It has long been a vexed question as to how far excellence of quality in plant products is determined by environment, and how far it can be considered as characteristic of the race. To the plant-breeder, therefore, who wishes to combine in one race excellence on various points a knowledge of the exact part played by hereditary influence and by environment in producing such qualities becomes essential.

Before considering the work of former observers on the subject it will be best to consider firstly what are the characters of the wheat grain which may be affected by change in environment; and secondly the economic significance of such changes.

The characters of the wheat grain which may be affected by change in environment are the following:—

1. *Colour.*—It has often been stated that certain types of soil will transform a white wheat into a red wheat. This subject has been dealt with at length in a former paper,[1] when it was shown that there is no evidence that such a change has ever taken place, except as the result of natural cross-fertilization.

2. *Size and Weight of the Grain.*—The size and absolute weight of the grain vary considerably both in different localities and also

[1] Howard and Howard, *Memoirs of the Department of Agriculture in India* (*Botanical Series*), Vol. II, No. 7, 1909.

in the same locality in different seasons. This character, although affecting the yield, cannot be regarded as a criterion of quality.[1]

3. *Composition.*—Much of the work on the subject of the effect of environment on the characters of the wheat grain has been concerned with the effect of change of environment on the nitrogen content of the grain—the nitrogen content being taken as the most convenient indication of the strength of a wheat. Unfortunately although, *as a rule*, the higher the nitrogen content the stronger the flour, nevertheless there are exceptions, some wheats high in nitrogen giving very weak flours.[2] The total nitrogen content is, therefore, not nearly so reliable a test of strength as that obtained by milling and baking the sample. Moreover the quality of a wheat does not depend entirely on the strength of the flour but on many other characters which go to form what is known as quality. Although a great deal of work has been done on the chemical composition of wheat and of wheat flour, yet no accurate relation has hitherto been found between the chemical composition and the bread-making value of wheat. Wood's[3] researches at Cambridge seem to indicate that the physical properties of the gluten are of greater importance than chemical composition.

4. *Consistency.*—The effect of environment on the consistency of the wheat grain, *i.e.*, its translucent or starchy appearance has been perhaps more thoroughly investigated than any other aspect of the question. There is no doubt that consistency depends very largely on the soil, on the available moisture and on the nutrition of the crop.[4] From the milling point of view the consistency of the wheat grain is of the highest importance and to some extent determines the value of the crop. Differences in consistency affect the market value of wheat in two ways. Firstly, millers like wheats of uniform consistency as in the conditioning or adjustment of water previous to grinding, it is an advantage to handle hard and soft wheats separately and a mixture of hard and soft wheats often leads to trouble and loss. Secondly, as a rule,

[1] Cserháti, *Ztschr. landw. Versuchsw. in Oesterreich*, 9 (1906), No. 10.
Hall, *Journal of the Board of Agriculture (England)*, Vol. XI, No. 6.

[3] Wood, *Journal of Agricultural Science*, Vol. II, 1907, p. 160.

[4] Howard and Howard, l. c.

translucent grains behave better in the mill and are more free grinding. As strong varieties of wheat are generally translucent, translucency is sometimes considered to be an indication of strength, but this is not always the case as translucent weak wheats also occur.[1] In spite of this fact, however, the consistency or appearance of the grain is a very important factor in the commercial valuation of a wheat.

5. *Quality.*—Good quality in wheaten flours has been defined by Humphries[2] as "the sum of excellence on several points," and these points are five in number: (1) flavour; (2) colour of the flour; (3) strength, *i.e.*, size and shape of loaf; (4) stability of dough; (5) yield of bread per sack of flour. It is clear that excellence on such points cannot be determined in any other way than by milling and baking tests. Many attempts have been made to obtain a criterion for the estimation of strength, but so far without success, and in seeking information on the effect of environment on the quality of the grain, it is absolutely necessary to submit the sample to a complete test in the mill and bakehouse.

Although during recent years a certain amount of attention has been paid to the effect of external conditions, such as soil, moisture and manurial treatment on the composition of wheat, but little work has been attempted on the much more important practical question of the influence of environment on the milling and baking qualities. The experiments described in this paper were designed to throw light on this point and also on the change in consistency.

Perhaps the most interesting results on the influence of external conditions on the composition of wheat are those of Le Clerc[3] in the United States, who found in the case of several durum wheats that in humid districts and under excessive irrigation the grain became starchy with a lower proteid content, while in the drier localities the grain remained hard and flinty with a much higher

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[1] Biffen, *Journal of Agricultural Science*, Vol. III, 1909.

[2] Humphries, *Quality in wheaten flour*, summary of a paper read before the Joint Session of the Chemistry, Botany and Agricultural Sections of the British Association at Winnipeg, 1909.

[3] Le Clerc, *Yearbook of the United States Department of Agriculture*, 1906, p. 198.

nitrogen percentage. No milling and baking tests, however, seem to have been made by Le Clerc, an omission which greatly reduces the value of his work.

In Canada, Shutt[1] has recently published some observations of a somewhat similar nature. It appears that in certain districts of the North-West when hard wheat is grown on newly cleared scrub land (locally known as "breaking"), there is a tendency to the production on such land of soft or so-called "piebald" wheat. Such grain is much lower in nitrogen content than the original hard wheat used for seed, and is considered in consequence to be a deteriorated product. The same seed (Red Fife) was sown on "breaking" and summer-fallow land, the soil moisture was determined and the resulting crops were analysed. With one exception it was found that both the nitrogen content and the consistency were affected by growth on the newly cleared land compared with the sample obtained on summer-fallow land. On the newly cleared land the grain was soft and starchy with a low nitrogen content, while that grown on the older wheat land was hard and high in proteids. In the following year (1906), the soft sample was sown on freshly cleared land and also on land which had been under wheat for some years. The former gave a soft sample low in proteid like that sown whereas the older wheat land produced a flinty grain high in nitrogen. The results are apparently due to the much greater moisture content of the newly cleared land which prolonged the growth, deferred ripening thus permitting of the deposition of more starch. It is unfortunate that no milling and baking tests seem to have been made with these samples, and that analytical data alone were secured.

Some attention has been paid to these questions by continental observers. Eriksson,[2] in Sweden, found that the consistency of the grain was of no systematic value and depended more on the season than the kind. Koernicke[3] at Popplesdorf, found that there was often a change from floury grain to flinty and also the reverse, and that these changes depended both on soil and season.

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[1] Shutt, *Report of the Fourth Annual Meeting of the Canadian Seed Growers' Association*, Ottawa, 1908, p. 52.

[2] Eriksson, *Die landw. Versuchs-Stationen*, Bd. 45, Heft 1 and 2, 1894.

[3] Koernicke, *Die Arten und Varietäten des Getreides*, Berlin, 1885.

Fruwirth[1] in a recent discussion of the subject concludes that quality varies with the season, soil and the nutrition of the crop, and that in Europe wheats become increasingly floury from East to West and from South to North.

The relation between the quality of wheat and the climatic conditions under which it is grown has been discussed at length by Schindler.[2] This observer considers that climate exercises a paramount influence on the quality of the wheat grown in any tract and that the influence of the race is of secondary importance. His most reliable data are drawn from a study of the Hungarian wheats. By considering the climatic conditions of the five tracts into which Hungary can be divided, Schindler shows that in those districts which have a larger rainfall and more moderate temperature, wheats are produced which are starchy and have larger, heavier grain and a lower protein content than those produced in the drier hotter tracts. An extension of these results was made to include the wheats of other countries. Evidence is also adduced to show that wheats when taken from one locality to another change in weight, size of grain and in protein content in a similar manner. As a result of these investigations Schindler considers that the wheat-growing districts of the world can be divided into "climatic provinces," and he states his conclusions as follows :—"*Im ganzen aber ergiebt sich aus den obigen Zahlen die sehr wichtige Thatsache, dass es nicht gerecht-fertigt ist, von der Korngrösse und dem Proteinanteil der Zucht abs von Rasseneigenschaften zu sprechen.* Sie mögen es ja bis zu einem gewissen beschränkten Grade sein, *allein die Konstanz der Rasse wird in dieser Beziehung durch der Einfluss des Klimas, teilweise auch des Bodens und der Kultur weitaus uberragt.*"

Schindler's conclusions are, however, open to the criticism that in considering the question too many assumptions have been made as to the identity of different races. His Hungarian results for instance are based on the assumption that all the wheat grown in the country is of one type. *A priori* it seems most unlikely that

[1] Fruwirth, *Die Zuchtung d. landw. Kulturpflanzen*, Bd. IV., 1907.

[2] Schindler, *Der Weizen in seinen Beziehungen zum Klima, und das Gesetz der Korrelation*, Munich, 1893.

this should be so. In considering the wheats of other countries no attention is paid to the question of variety at all, and this is a very serious objection to the acceptance of his results as an accurate study of the subject.

More recently Raum[1] at Munich undertook a study of the morphological changes induced in the grains of cereals by climatic conditions. Thirty-five different kinds of wheat mostly of foreign origin were grown for three years and the weight of 1,000 grains and the measurements of the length and breadth of the grain compared with that of the original seed. The results were not very conclusive. In general it was shown that wet summers produced heavier grain than dry years, but it was not possible to determine any progressive change in the length and breadth of the grains by continued cultivation in a new locality. As regards the consistency it was noticed that the North German and exotic kinds became more and more flinty each year and tended to resemble the flinty Bavarian kinds.

In England in addition to the observations of Voelcker[2] (who found at Woburn that as the relative proportions of lime and magnesia in the soil approach nearer and nearer to the ratio 1 : 1 so the wheat grain tends to become more glutinous and hard), a considerable amount of attention has been paid to the effect of external conditions on the milling and baking qualities of wheat by Humphries and Biffen.[3] These investigators grew two wheats differing in strength on seven types of soil and found that while the soil had a considerable influence on the strength yet on all soils the stronger variety, Red Lammas, gave the better result. The bakers' marks of Red Lammas varied from 70 on warp land to 50 on a stony clay soil.

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[1] Raum, *Zur Kenntniss der morphologischen Veranderungen der Getreidekörner unter dem Einflusse kleimatischer Verhaltnisse*, Munich, 1906.

[2] Voelcker, *Journal of Royal Agricultural Society of England*, Vol. 68, 1907, p. 265.

[3] Humphries and Biffen, *Journal of Agricultural Science*, Vol. II, 1907, p. 6.

II. THE INDIAN PROBLEM.

The conditions, both as regards soil and climate under which wheat is grown in India, vary very widely. There are several well-marked wheat tracts differing from each other in the nature of the soil, in the sources of moisture and in the growth period. Wheat-growing on the Chenab colony, for example, is very different from that on the black cotton soils of the Narbada valley in the Central Provinces.

The wheat tracts of India fall into two main groups differing both as regards soil and also as regards the source of moisture. The more important of these regions is the alluvium of the Indo-Gangetic plain stretching from Bihar on the East through the United Provinces and the Punjab to Sind on the Western Coast. In parts of Bihar, wheat is grown on low-lying high moisture retaining heavy loams without irrigation. In Oudh, wells supplement the rainfall, while in the Doab between the Jumna and the Ganges and in the western Districts of the United Provinces canal water is largely employed. Well irrigation is again met with in the Eastern Punjab while in other portions of the Province the wheat crop obtains most of its moisture either from perennial or inundation canals. In Sind, inundation from the Indus takes the place of the monsoon. The predominant feature of the wheat tracts of the plains is some form of irrigation and the crop may be either entirely or only partially watered.

The second group of wheat-growing tracts in India is found in Peninsular India principally on the black cotton soils of Central India and Bombay. Here irrigation is largely confined to the second class wheat soils of Bombay, most of the wheat of the Peninsula being raised on the moisture left in the soil after the previous monsoon.

In both of these regions the first consideration is moisture. If the tract is commanded by a perennial canal the choice of soil

is not of paramount importance, any type of loam being used for wheat. Where the natural rainfall is supplemented from wells as in Oudh, wheat is confined to rather heavy loams with a moderate capacity for retaining moisture. In tracts which are not irrigated at all as in North Bihar and the Central Provinces, the type of soil is of the greatest importance and only heavy soils which retain moisture well are used for wheat.

Another factor, in addition to soil and moisture supply, is of great importance in wheat-growing in India, namely, the length of the growth period in the various tracts. The wheats of Peninsular India and Bihar are rapidly maturing forms and in these regions any wheats requiring a longer period for growth than those now in cultivation are bound to be unsuitable. In these tracts wheats are sown towards the end of October and reaped during the second half of February and the first half of March. In the United Provinces and the Eastern Punjab the harvest is later, while in the canal colonies of the Punjab wheat is ripe at the end of April.

Besides these cultural differences, certain of the wheat tracts of India have gained a reputation for producing certain types of grain. Thus the wheat exported from the Narbada valley gives a flour of a very chalky white hue, while the wheat from the Muzaffarnagar District has a very plump soft grain—other tracts such as parts of Bengal appear to produce small flinty grains. It is obvious that in the introduction of new varieties it becomes a matter of great moment to find out whether such new wheats will retain their characteristics in new districts or whether they will acquire to some extent the characters of the wheat generally grown in such tracts. If, as appears probable from the results already obtained, it is found that environment exercises a very marked effect on the quality, it is clear that one of the problems in the improvement of wheat in the Indian Empire will be to ascertain what are the characters of the wheat crop in the various tracts, the extent of these tracts and how far it is possible to usefully distribute new and improved varieties. This will enable a scientific scheme of seed distribution to be drawn up for the whole of India.

Little useful information on the quality of the wheat grown in the various tracts can be gained from an examination of the crop as grown by the cultivators as their fields are so mixed and often contain at least a dozen different botanical varieties often belonging to two subspecies. Further, these mixtures vary from year to year as many of the cultivators do not keep their own seed but obtain the seed wheat from the grain dealers. While an examination of these variable mixtures gives a general idea of the consistency of the crop likely to be raised in any tract, they are not of much use for milling and baking tests as they always contain so many classes of red and white grain often mixed with durum wheat.

The method adopted in this investigation is to compare, as regards consistency, absolute weight, milling and baking qualities, several pure types of wheat grown at various stations according to the manner in vogue among the best cultivators in each place. Care is taken to select really typical wheat soil and to carry out the cultivation according to the ordinary practice of the locality. In this manner the product fairly represents the result which would in practice be obtained by introducing such a wheat among the cultivators. The several stations have been selected so as to include as many as possible of the most important wheat-growing tracts of the Indo-Gangetic plain from the canal colonies of the Punjab to the banks of the Ganges in Bengal and also two stations representative of the black cotton soil tracts of Peninsular India. At each station several wheats are grown of markedly different qualities. These wheats are all pure types, that is, they are both agriculturally and botanically uniform. Full cultural details are kept and thus the same wheat grown at the different stations can be compared both as regards its behaviour in the field and as regards the character of the resulting produce.

The weight of 1,000 grains is obtained, the consistency is determined and the samples are then sent to be milled and baked in England by Mr. A. E. Humphries,[1] the Chairman of the Home-grown Wheat Committee of the Incorporated National Association

[1] For an account of the method adopted in carrying out these milling and baking tests, see Humphries and Biffen, *Journal of Agricultural Science*, Vol. II, 1907, p. 1.

of British and Irish Millers, and a well-known authority on the milling and baking of wheat. It is hoped to grow these wheats for several years at each station, the seed used in each succeeding year being drawn from the wheat produced at the same station in the preceding year.

When a sufficient number of well-chosen types of wheat, representative of the various classes grown, have been tested for several years in this manner it will be possible to determine with precision how far milling and baking qualities are affected by environment and whether such a change is progressive or whether it takes place once for all. The type of wheat best suited to the various tracts will at the same time be discovered, and it may be possible to draw up a scientific scheme of seed distribution for India. Unprofitable work in trying to grow in any tract wheats entirely unsuited to it will in future be prevented.

Strong free-milling wheats can certainly be grown in some tracts of India, others at the present time are producing weak soft whites of poor milling qualities. It is obviously important to discover how far the profitable cultivation of high quality wheats can be extended and whether in the tracts now growing soft grain, strong wheats can be made to retain their strength and high milling qualities.

The results obtained in 1908 and 1909 are of considerable interest and during the present wheat-growing season, 1909-10, the experiments have been considerably extended.

III. THE RESULTS OBTAINED IN 1908 AND 1909.

A. Muzaffarnagar white.

During the season 1907-08, Muzaffarnagar white, (*T. vulgare* Vill. var. *græcum* Kcke.) a weak soft white type obtained from Muzaffarnagar was grown at three stations, Lyallpur, Muzaffarnagar and Púsa. At Lyallpur and Muzaffarnagar the wheat was grown under canal irrigation while at Púsa it was raised on the moisture left in the soil from the previous monsoon. Both in appearance, consistency, nitrogen content and milling and baking value the three resulting samples varied widely as will be seen from the following table :—

Consistency, composition and baking value of Muzaffarnagar white grown at three stations in 1907-1908.

Where grown.	Colour and Consistency.	% Nitrogen (Leather).	Order in baking value (Humphries).
1. Púsa ..	Amber, mostly hard and semi-hard.	1·86	Fifth.
2. Lyallpur ..	Dull white, mostly soft and mottled.	1·50	Eighth.
3. Muzaffarnagar ..	White, entirely soft.	1·38	Ninth.

The great differences between the Púsa grown sample and the other two suggested the desirability of repeating the tests on a wider basis and accordingly a fresh supply of Muzaffarnagar white seed was obtained by one of us from Muzaffarnagar and arrangements were made to grow it under normal conditions on typical wheat land at the following stations—Púsa, Bankipore, Dumraon, Partabgarh, Cawnpore, Orai, Aligarh, Meerut and Lyallpur. The sample contained 90% soft grains and 10% hard. It will be seen from the accompanying map that these stations represent most of the important wheat-growing tracts. Púsa is

representative of North Bihar ; Bankipore and Dumraon of South Bihar ; Partabgarh of Oudh ; Cawnpore of the Middle Doab, while the Upper Doab is represented by Aligarh and Meerut. Lyallpur is situated in a canal colony of the Punjab and Orai represents the Bundelkhand. During 1909-10, Hoshangabad has been included, a station typical of the true black cotton soil found in the Narbada valley.

The results obtained at the nine stations in 1908-09 proved to be still more interesting than the preliminary results obtained at Lyallpur, Muzaffarnagar and Púsa in 1907-08.

1. *Cawnpore.*—This sample was grown in the Botanical area at the Cawnpore Experiment Station by the Economic Botanist. Cawnpore is typical of the large wheat-growing tract known as the Middle Doab. The cultural and other details are given in the following table :—

Trial of Muzaffarnagar white at Cawnpore, 1908-09.

Cultural and other details.

1.	Type of soil	Typical wheat loam known locally as *dumat.*
2.	Previous crop	Oats.
3.	Manuring	Nil.
4.	Preparation of the land for the wheat crop	Ploughed six times before sowing on 12-4-08, 3-7-08, 27-8-08, 11-9-08, 28-9-08 and 6-10-08.
5.	Date and method of sowing ..	Sown on 24-10-08, behind the country plough and levelled with the beam.
6.	Seed rate	120lbs. to the acre.
7.	Rainfall, April to Oct. and during growth period	31·68″ during the seven months previous to sowing, 0·25″ during the growth period.
8.	Irrigation	Watered twice from the canal on 22-11-09 and 15-1-09.
9.	Date of harvesting	3-4-09.
10.	Growth period	161 days.
11.	Consisteney of sample	8% soft, 48% intermediate and 39% hard.
12.	Nitrogen content	2·37%
13.	Weight of 1,000 grains	35·69 grammes.
14.	Order of merit in commercial value ..	First.

2. *Púsa.*—This sample was grown in the Botanical area at Púsa in North Bihar on typical wheat loam of high moisture retaining capacity. This soil is low in phosphoric acid but contains about 30% of calcium carbonate.

Trial of Muzaffarnagar white at Púsa, 1908-09.

	Cultural and other details.	
1.	Type of soil	Heavy loam.
2.	Previous crop	Wheat in 1907-08. Fallow during the *kharif* of 1908.
3.	Manuring	Nil.
4.	Preparation of the land for the wheat crop	Ploughed 7 times during the hot weather and rains.
5.	Date and method of sowing ..	Sown on 26-10-08 behind the country plough and levelled twice with the beam.
6.	Seed rate	60lbs. to the acre.
7.	Rainfall, April to October and during the growth of the crop.	18·84″ April to October and 0·38″ during the growing period.
8.	Irrigation	Once in December 1908.
9.	Date of harvesting	25-3-09.
10.	Growth period	151 days.
11.	Consistency of sample	16% soft, 59% intermediate and 25% hard.
12.	Nitrogen content	2·0%.
13.	Weight of 1,000 grains	38·35 grammes.
14.	Order of merit in commercial value ..	Second.

3. *Partabgarh.*—This sample was grown by the Assistant-Director of Agriculture at the Partabgarh Experiment Station on typical wheat loam. Similar soil at the station contained 0·2% phosphoric acid, 0·36% potash and 0·042% of nitrogen.

Trial of Muzaffarnagar white at Partabgarh, 1908-09.

	Cultural and other details.	
1.	Type of soil	Typical wheat loam known locally as *dorasa*.
2.	Previous crop	Sugarcane, reaped in February 1908.
3.	Manuring	Nil.
4.	Preparation of the land for the wheat crop.	Ploughed five times with the Watts plough (10-7-08, 25-7-08, 6-8-08, 18-8-08, 25-8-08) and five times with the country plough (4-9-08, 14-9-08, 21-9-08, 29-9-08 and 5-10-08.)
5.	Date and method of sowing ..	Sown on 15-10-09, behind the country plough.
6.	Seed rate	108lbs. per acre.
7.	Rainfall, April to October and during the growth period.	22·20″ during the seven months previous to sowing, 0·42″ during the growth period.
8.	Irrigation	Twice from well on 27-10-08 and 31-12-08.
9.	Date of harvesting	29-3-09.
10.	Growth period	165 days.
11.	Consistency of sample	36% soft, 33% intermediate and 31% hard.
12.	Nitrogen content	1·79%.
13.	Weight of 1,000 grains	40·02 grammes.
14.	Order of merit in commercial value ..	Third.

4. *Dumraon.*—This sample was grown by the Deputy Director of Agriculture, Bengal, at the Dumraon Experiment Station on typical wheat land by the method ordinarily adopted by the cultivators in the neighbourhood.

Trial of Muzaffarnagar white at Dumraon, 1908-09.

	Cultural and other details.	
1.	Type of soil	A clayey loam.
2.	Previous crop	*Aus* paddy.
3.	Manuring	Cowdung at the rate of 83 mds. per acre on 5-10-08.
4.	Preparation of the land for the wheat crop.	Ploughed three times on 15-9-08, 6-10-08, and 17-10-08, and irrigated on 17-9-08 and 8-10-08, from the canal.
5.	Date and method of sowing ..	Sown on 18-10-08 with the single coultered native drill, after which the land was left rough.
6.	Seed rate	100lbs. per acre.
7.	Rainfall, April to October, and during the growth period.	19·93″ during the seven months previous to sowing, 0·9″ during the growth period.
8.	Irrigation	Watered four times from the canal on 6-11-08, 10-12-08, 9-1-09 and 26-2-09.
9.	Date of harvesting	17-3-09.
10.	Growth period	150 days.
11.	Consistency of sample	72% soft, 21% intermediate, and 7% hard.
12.	Nitrogen content	1·52%.
13.	Weight of 1,000 grains	43·67 grammes.
14.	Order of merit in commercial value ..	Fourth.

5. *Aligarh.*—This sample was grown by the Deputy Director of Agriculture of the United Provinces, Northern Circle, at the recently acquired Experimental Station at Aligarh in the Upper Doab.

Trial of Muzaffarnagar white at Aligarh, 1908-09.

Cultural and other details.

1.	Type of soil	Light loam—fairly typical wheat land.
2.	Previous crop	Cotton.
3.	Manuring	Poudrette containing 50lbs. nitrogen per acre.
4.	Preparation of the land for the wheat crop.	Ploughed twice with the Watts plough on 10-2-08, 11-7-08 and eight times with the country plough on 23-8-08, 7-9-08, 11-9-08, 18-9-08, 3-10-08, 4-10-08, 3-11-0 and 6-11-08.
5.	Date and method of sowing ..	Sown on 8-11-09 behind the country plough.
6.	Seed rate	100lbs. per acre.
7.	Rainfall, April to October, and during the growth period.	34·92″ April to October, 1·48″ during the crop.
8.	Irrigation	Four times—on 8-11-08, 8-12-08, 9-2-09 and 9-3-09.
9.	Date of harvesting	5-4-09.
10.	Growth period	158 days.
11.	Consistency of sample	76% soft, 15% intermediate, and 9% hard.
12.	Nitrogen content	1·30%.
13.	Weight of 1,000 grains	42·54 grammes.
14.	Order of merit in commercial value ..	Fifth.

6. *Meerut.*—This sample was grown by a local *zamindar* near Meerut in the country fashion. This station was selected as the general agricultural conditions of this tract are identical with those in the neighbouring Muzaffarnagar District, and it may, therefore, be taken as the natural home of Muzaffarnagar white.

Trial of Muzaffarnagar white at Meerut, 1908-09.

Cultural and other details.

1.	Type of soil	Typical wheat loam.
2.	Previous crop	Juar.
3.	Manuring	Nil.
4.	Preparation of the land for the wheat crop.	The field was ploughed 9 times with the country plough—3 times during the rains and 6 times afterwards.
5.	Date and method of sowing ..	Sown on 21-10-09, behind the country sowing plough.
6.	Seed rate	60lbs. per acre.
7.	Rainfall, April to October, and during the growth period.	34·70″ April to October, and 2·73″ during the growth period.
8.	Irrigation	Three times—20-11-08, 1-1-09 and 15-2-09.
9.	Date of harvesting	12-4-09.
10.	Growth period	173 days.
11.	Consistency of the sample ..	Through an oversight this was not accurately ascertained, but the sample greatly resembled that grown at Aligarh.
12.	Nitrogen content	1·34%.
13.	Weight of 1,000 grains	Not ascertained.
14.	Order of merit in commercial value ..	Sixth.

7. *Bankipore.*—This sample was grown by the Deputy Director of Agriculture at the recently acquired Experiment Station at Bankipore.

Trial of Muzaffarnagar white at Bankipore, 1908-09.

	Cultural and other details.	
1.	Type of soil	Heavy clay.
2.	Previous crop	Maize (removed in Oct. '08).
3.	Manuring	Nil.
4.	Preparation of the land for the wheat crop.	Ploughed 6 times with the country plough on 1-11-08.
5.	Date and method of sowing ..	Sown on 11-11-08, with the local one coulter drill.
6.	Seed rate	98lbs. per acre.
7.	Rainfall, April to October, and during the growth period.	17·46″ from April to October, 2·79″ during the growth period.
8.	Irrigation	Irrigated on 1-11-08 before sowing and once on 25-1-09.
9.	Date of harvesting	24-3-09.
10.	Growth period	133 days.
11.	Consistency of the sample	83% soft, 13% intermediate and 4% hard.
12.	Nitrogen content	1·34%.
13.	Weight of 1,000 grains	38·95 grammes.
14.	Order of merit in commercial value ..	Seventh.

8. *Lyallpur.*—This sample was grown at the Lyallpur Experiment Station in the Chenab Colony by the Professor of Agriculture of the Punjab Agricultural College. The conditions at Lyallpur are typical of those obtaining in the Chenab Colony which furnishes a large portion of the wheat exported from Karachi. It is, therefore, very important that Lyallpur should be included in this scheme of experiments.

Trial of Muzaffarnagar white at Lyallpur, 1908-09.

Cultural and other details.

1.	Type of soil	Typical wheat land of the Lyallpur District.
2.	Previous crop	Wheat 1907-08, fallow during the *kharif* of 1908.
3.	Manuring	Nil.
4.	Preparation of the land for the wheat crop.	Ploughed six times on 19-7-08, 9-8-08, 27-8-08, 9-9-08 and 22-9-08 and irrigated twice on 14-7-08 and 21-10-08.
5.	Date and method of sowing.	Sown on 9-11-08 behind the country plough, levelled with the *Sohaga.*
6.	Seed rate	64lbs. per acre.
7.	Rainfall, April to sowing time and during the growth period.	18·26″ April till sowing time, 3·51″ during the growth period.
8.	Irrigation	Three times on 26-1-09, 27-2-09 and 3-4-09.
9.	Date of harvesting	1-5-09.
10.	Growth period	173 days.
11.	Consistency of the sample	75% soft, 20% intermediate and 5% hard.
12.	Nitrogen content	1·52%.
13.	Weight of 1,000 grains	37·08 grammes.
14.	Order of merit in commercial value ..	Eighth.

9. *Orai.*—This sample was grown by the Deputy Director of Agriculture, United Provinces, Central Circle, at the Orai Experiment Station in Bundelkhand. The soil was a black moisture retaining clay known as *mar*.

Trial of Muzaffarnagar white at Orai, 1908-09.[1]

	Cultural and other details.	
1.	Type of soil	Typical wheat land known locally as *mar*.
2.	Previous crop	Gram in the *rabi* of 1907-08.
3.	Manuring	Nil.
4.	Preparation of the land for the wheat crop.	Bakhared four times—8-6-08, 23-9-08, 9-10-08 and 20-12-08.
5.	Date and method of sowing ..	Sown on 19-10-08 and re-sown on 21-12-08 behind the country sowing plough.
6.	Seed rate	108lbs. per acre.
7.	Rainfall, April to Oct., and during the growth period.	27·90″ April to October, and 3·80″ during the growth period.
8.	Irrigation	Watered three times on 19-10-08, 22-11-08 and 10-2-09.
9.	Date of harvesting	25-4-09.
10.	Growth period	125 days.
11.	Consistency of the sample	95% soft and 5% intermediate.
12.	Nitrogen content	1·93.
13.	Weight of 1,000 grains	30·97 grammes.
14.	Order of merit in commercial value ..	Ninth

[1] This sample is to some extent abnormal as the plot had to be re-sown late in December.

These nine samples were submitted to Mr. A. E. Humphries for milling and baking tests in May 1909 and his report is given below.

REPORT BY MR. A. E. HUMPHRIES, PAST PRESIDENT OF THE INCORPORATED NATIONAL ASSOCIATION OF BRITISH AND IRISH MILLERS, ON THE NINE SAMPLES OF MUZAFFARNAGAR WHITE SENT FROM INDIA IN 1909.

Muzaffarnagars.

"I received 10 lots of this name. One of them, No. 7, is described as Beardless Muzaffarnagar. I know nothing of this wheat as regards its other botanical characteristics, but from my standpoint, as a miller, it is substantially different to the others, and I propose dealing with that separately later on. I understand that the other 9 lots were sown, each one at a different place to test the effect of environment on quality. The results are striking especially if the seed sown in each case had been taken from the same original bulk. I examined the wheats by eye and put them in the following order as regards appearance :—

No. 11. Cawnpore.
„ 15. Púsa.
„ 12. Partabgarh.
„ 13. Dumraon.
„ 10. Aligarh.
„ 9. Meerut.
„ 14. Bankipore.
„ 8. Lyallpur.
„ 16. Orai.

The Orai was a dingy-looking shrivelled wheat, the Lyallpur had a peculiar hue which may have been caused by its having been cut at a much earlier stage of ripeness than the others. There is, in my opinion, a difference of several shillings per quarter in money value between the best and the worst of these lots. This type of

wheat would commend itself to those millers who want to produce soft white flour. It would find a ready sale, say in Ireland, or some parts of the N. E. of England, or in other parts in the absence of English or Australian wheats, and it may be good for biscuit and pudding making, but to me, as a miller, making bread flour for the London district, it is not a desirable type of Indian wheat. It behaves poorly in milling after conditioning, and this remark applies to all of them, particularly to the Orai and Lyallpur lots. Some of the lots contain a proportion of translucent berries. They help the milling and improve the results in bread, but diminish the mere whiteness of the flour. The baking trials leave them very much in the same order as that I assigned to them by appearance, except that the poor looking Lyallpur lot made better bread than its appearance led me to expect, and the Bankipore yielded the worst bread of all on each trial. Some of them, notably the 3 at the head of the list, and in particular the Cawnpore lot, made loaves of good external appearance; the rest yielded loaves with a pale sickly crust, and are, in my opinion, wheats which a British miller would not willingly use by themselves for any sort of bread flour. The Cawnpore lot also yielded bread of relatively good, but still poor flavour. For my own guidance, I have for many years recorded my opinion of flours in marks, as a more convenient means of recording or expressing opinion than words, and though the scale adopted is a purely arbitrary one, and expresses nobody's opinions but those of the people immediately concerned in the baking operations so recorded, it may make the comparisons more intelligible if I give them herein, 'Stability' means the facility with which large masses of dough can be handled by the baker, 'strength' the volume and shape of loaf.

		Stability.	*Strength.*
No. 11.	Cawnpore	84	75
„ 15.	Púsa	84	75
„ 12.	Partabgarh	82	75
„ 13.	Dumraon	78	63

		Stability.	*Strength.*
No. 8.	Lyallpur	68	68
„ 10.	Aligarh	70	60
„ 9.	Meerut	70	60
„ 16.	Orai	64	60
„ 14.	Bankipore	68	52

I am supposing that this record of baking results will be of value in arriving at the influences of soil, climate and water-supply, but it must be remembered that other points besides baking value go to the making up of commercial value, and having regard to all the points mentioned concerning these wheats, I think my original estimate, based on appearance, is the correct summary of their relative commercial merits. I should like to add that the Home Grown Wheat Committee of the National Association of British and Irish Millers tested, in the earliest years of its existence, the influence on quality of varying sets of natural English conditions. We tested two varieties in each locality and found very great differences in both due to environment, but although the effect of environment was not the same in each case on both varieties, the better wheat in every case yielded the better bread. In our view this showed that the effect of breed was predominant. It would be interesting to see whether the same results would be obtained in India if two or more varieties, each able to thrive under the varying local conditions, were tested in a similar way."

It is interesting to notice that Mr. Humphries considers that there is a difference of several shillings per quarter in money value between the best and the worst of these samples, and that he is further of opinion that "the results are striking, especially if the seed sown in each case had been taken from the same original bulk." This was the case—the seed was obtained from a local *zamindar* in Muzaffarnagar and contained 90% soft grain and 10% hard. For the sake of convenience the results with Muzaffarnagar in 1908-09 are summed up in the following table :—

Comparative value of Muzaffarnagar white grown at nine stations in 1908-09.

Where grown.	Consistency.			Weight of 1,000 grains in grammes.	Nitrogen percentage.	Bakers' marks.		Order of merit in commercial value.
	Soft.	Intermediate.	Hard.			Stability.	Strength.	
Cawnpore	8	48	39	35·69	2·37	84	75	First.
Púsa	16	59	25	38·35	2·00	84	75	Second
Partabgarh	36	33	31	40·02	1·79	82	75	Third.
Dumraon	72	21	7	43·67	1·52	78	63	Fourth.
Aligarh	76	15	9	42·54	1·30	70	60	Fifth.
Meerut	—	—	—	—	1·34	70	60	Sixth.
Bankipore	83	13	4	38·95	1·34	68	52	Seventh.
Lyallpur	75	20	5	37·08	1·52	68	68	Eighth.
Orai	95	5	0	30·97	1·93	64	60	Ninth.

B. Punjab wheats grown at Lyallpur and Cawnpore.

In 1908 the types of wheat grown in the Punjab were botanically and agriculturally classified at Lyallpur and twenty-five distinct wheats were distinguished. An account of this work is given in a previous paper.[1] These 25 wheats were grown in the Botanical area at Cawnpore by one of us in 1908-09, and a comparison was made between the consistency of the original seed obtained from Lyallpur with that which resulted from the Cawnpore harvest in 1909. The results are given in the following table :—

[1] Howard and Howard, *Memoirs of the Department of Agriculture in India (Botanical Series)*, Vol. II, No. 7, 1909.

The change in consistency of the 25 types of Punjab Wheats when grown at Cawnpore in 1908-09.

Type No.	Botanical name.	Consistency at Lyallpur in 1908.			Consistency at Cawnpore in 1909.			Nitrogen percentage.		Weight of 1,000 grains in grammes.	
		Soft.	Intermediate.	Hard.	Soft.	Intermediate.	Hard.	Lyallpur.	Cawnpore.	Lyallpur.	Cawnpore.
	T. durum Desf.										
1	Var. *melanopus* Al.	9	29	62	0	0	100	1·75	2·60	45·80	43·39
2	Var. *africanum* Kcke. ..	0	9	91	2	5	93	2·61	1·97	50·74	54·65
3	Var. *leucurum* Al.	0	4	96	24	25	51	2·20	1·56	54·91	52·48
	T. compactum Host.										
4	Var. *erinaceum* Kcke. ..	17	46	37	19	8	43	2·14	1·63	22·38	27·71
5	Var. *linaza* Kcke.	58	42	0	25	35	40	1·78	1·49	29·54	32·60
6	Var. *Wernerianum* Kcke. ..	100	0	0	100	0	0	1·62	1·80	31·56	34·48
7	Var. *Humboldti* Kcke. ..	23	49	28	39	33	28	1·71	1·58	25·23	31·53
	T. vulgare Vill.										
8	Var. *barbarossa* Al.	21	31	48	0	6	94	1·52	2·16	32·16	30·38
9	Var. *fuliginosum* Al.	4	15	81	23	23	54	2·01	1·60	32·02	37·06
10	Var. *erythroleucon* Kcke. ..	51	49	0	0	1	99	1·40	1·75	33·55	35·61
11	„ ..	75	25	0	61	29	10	1·34	1·65	35·05	29·14
12	„ ..	0	27	73	1	3	96	1·50	2·00	36·40	35·34
13	Var. *ferrugineum* Al. ..	20	36	44	5	7	88	1·57	1·93	35·04	30·37
14	Var. *erythrospermum* Kcke. ..	29	71	0	0	0	100	1·37	1·90	35·70	35·32
15	„ ..	68	32	0	1	8	91	1·43	2·16	36·44	33·12
16	Var. *græcum* Kcke.	88	12	0	34	1	65	1·39	2·08	33·69	31·38
17	Var. *Delfii* Kcke.	25	31	44	7	8	85	1·42	1·71	35·15	38·54
18	„ ..	69	31	0	2	3	95	1·39	2·26	34·53	31·00
19	Var. *leucospermum* Kcke. ..	83	17	0	1	5	94	1·35	2·29	31·58	22·20
20	Var. *alborubrum* Kcke. ..	73	27	0	0	0	100	1·43	2·10	33·59	32·39
21	„ ..	62	23	15	0	0	100	1·45	2·54	32·40	30·48
22	Var. *milturum* Al.	14	43	43	1	1	98	1·38	2·10	35·07	38·55
23	„ ..	100	0	0	98	0	2	1·35	1·95	33·13	33·83
24	Var. *albidum* Al.	66	16	16	4	11	85	1·37	1·87	36·48	38·04
25	„ ..	92	8	0	99	0	1	1·62	1·52	38·26	41·99

With one exception it will be observed that the common wheats have increased in nitrogen content at Cawnpore, and that are also corresponding changes in consistency. In all cases nitrogen content and the weight of 1,000 grains must be considered together. When the absolute weight is low, the nitrogen content naturally increases, apart from the effect of environment.

Five of the common wheats (Types 10, 12, 15, 17 & 21) were sent to Mr. Humphries for milling and baking tests and his report is given below. It will be noticed that while none of these wheats are particularly strong, some of them mill well and all the white ones (Types 10, 12, 17 & 21) are superior to the Karrachi wheats of commerce :—

Punjab Group.

"Nos. 1 to 5 inclusive were also labelled as Punjab 10, Punjab 12, Punjab 15, Punjab 17 and Punjab 21, respectively. In arranging the sequence of groups herein, I have had regard to the hardness of the constituent wheats ; therefore, it may be correctly inferred that these wheats are distinctly harder than those already dealt with. Of this group, No. 3 (Punjab 15), the only red one in it, is the least hard, but even that one milled after conditioning very freely ; indeed, on the one point of behaviour in the mill all this group stand highly. Nos. 1, 2, 4 & 5 are of very attractive appearance, and because any one lot of wheat should be even in texture, No. 5 is the best of the group, because it consists entirely of beautifully translucent grain. As a consequence, the flours from this group are not white or soft. Nos. 4 & 5 yield yellow flours, but they are of attractive appearance, and bake well. The bread from No. 5 was of a pleasant flavour. This group provides no surprises as regards strength. The best one on that point is No. 5, but even that behaves like good ordinary Indian wheat. However, all of the white ones are superior to the Kurrachee wheats of commerce. The red one (No. 3) is not 'well grown' and does not 'take the eye' so much as the others of this group."

It will be clear from the milling and baking reports on the nine Muzaffarnagars and on the five Punjab types grown at Cawnpore how exceedingly important it is to consider appearance and

milling quality in the wheats exported to England. It is to the interests both of the cultivator and of all concerned in the wheat trade of India that they should deal with a more valuable product than the present wheats of export. Great care should be taken to place Indian wheat on the market in a clean, dry and uniform condition and as far as possible grain uniform in consistency should be aimed at.

Our experience in Púsa, Cawnpore and Lyallpur shows that the Indian cultivator has much to learn in the growing of wheat and especially in the conservation of soil moisture, in the preliminary preparation of the land, the use of good seed and in the regulation of the irrigation water. In the canal colonies of the Punjab especially great room for improvement exists in these respects. In this important wheat tract the wheat lands should be weathered during the hot season and ploughed occasionally during the summer months. The resulting partial sterilisation of the soil would do much to improve the nitrogen supply of the next crop, any rainfall would be absorbed and a far better seed bed and tilth obtained for the wheat crop. Smaller irrigation compartments should be made, as little water as possible should be used, and the last irrigation should not be delayed too long. In the rest of the Indo-Gangetic plain the substitution of light iron soil inverting ploughs in the place of the country plough for opening out the soil during the hot weather and during the early portion of the monsoon would lead to a vast improvement in wheat-growing. Fewer ploughings with the country plough are desirable towards the end of the preparation so as to conserve soil moisture and produce a better seed bed.

The experiments dealt with in the present paper are only a portion of those in progress on the influence of environment on the quality of Indian wheat. The full scheme of work now in hand is described in the next section.

IV. THE EXPERIMENTS NOW IN PROGRESS.

The present paper deals only with the earlier experiments and principally with those in which Muzaffarnagar white was used. This wheat was originally selected as it was the only pure wheat available in sufficient quantity for the experiments and also because it represents the soft whites now so much exported to Europe. It is a good example of a weak, soft white wheat yielding a chalky flour. Three other wheats have since been added, namely, three Púsa selections representing (1) a free-milling, high nitrogen, uniformly hard white durum; (2) a soft, mellow, free-grinding, white wheat of great strength and high bread-making quality; and (3) a hard, white, free-milling, strong wheat not unlike Canadian Fife in shape and quality. The influence of environment on these soft strong and hard strong wheats will be of great interest, and it will be seen whether or not a soft strong wheat will retain its strength in localities such as South Bihar, Bundelkhand, the Narbada Valley, the Upper Doab and on the Chenab Colony of the Punjab.

After growing each of the four selected wheats at each station for several years, the various samples will be taken back to their original home, grown side by side and again tested to see if they revert to their original character and become uniform in all respects. The Muzaffarnagars will be grown at Meerut by a local *zamindar*, while the three Púsa selections will be grown in the Botanical area at Púsa.

Besides these trials which will form the main portion of the investigations, other subsidiary experiments will be carried out. The 25 Punjab types of wheat will be grown side by side in the Botanical area at Cawnpore for the next few years and their consistency examined every year. In 1909-10 and following years they will also be grown in the Botanical area at Púsa and similarly examined and compared with the Cawnpore produce. These 25 Punjab types which are absolutely pure both as regards botanical

and agricultural characters form a very convenient material for the study during several years of changes in consistency on a large number of very different wheats. The 25 types include 3 macaroni wheats, 4 dwarf wheats and 18 common wheats. In a similar manner the Bengal types of wheat at present growing in the Botanical area at Púsa will be grown in the Botanical area at Cawnpore from 1910 onwards.

A further experiment on the influence of environment on the milling and baking qualities of wheat is in progress at Cawnpore and Púsa, and it is hoped to extend this experiment to the Chenab Colony of the Punjab in 1910. This trial consists in the influence of weathering[1] on the yield and quality of the same variety grown side by side on quarter acre plots, one of which has been weathered during the hot weather and the other in which cultivation has been postponed till after the monsoon has set in. Both the consistency and the milling and baking qualities of these samples will be compared, and it is expected that the results will not be without interest and value to India.

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1 The exposure of the alluvial soil of the plains of India by several ploughings to the sun and air during the intensely hot dry weather of April, May and June has an astonishing effect on the yield of the succeeding wheat crop and undoubtedly increases the nitrogen available in the soil as is seen in the dark green luxuriant foliage. When the soil for wheat is not weathered during this hot dry period, the crop is yellow and stunted and exhibits all the characteristics of nitrogen hunger.

The explanation of the extraordinary manurial effect of weathering is no doubt due to the partial sterilisation of the soil by the intense dryness, heat and light of an Indian hot weather. In all probability these causes bring about a similar result to that produced by artificial heating and by poisons such as has been found in England by Russell and his pupils (vide *Journal of Agricultural Science*, Vol. III, 1909, p. 111). These investigators have found that partial sterilisation of the soil kills off the phagocytes which live on bacteria, and also large soil organisms inimical in other ways to bacteria. At the same time the soil bacteria are killed off, but the spores remain which germinate and rapidly multiply when the soil is moistened. The new bacterial cultures increase at an enormous rate and the resulting nitrogenous plant food becomes so great that growth is stimulated. Russell's researches seem to afford an adequate explanation of the extraordinary manurial effect of weathering Indian wheat land. The Imperial Agricultural Bacteriologist has agreed to investigate the bacteriological aspect of this question in India. For weathering during the hot season iron ploughs are more effective than the native wooden plough. This is no doubt due to the better soil inversion produced by the former, resulting in a more complete weathering and sterilisation of the soil.

We believe it will be found that not only the yield but also the quality of the crop is improved by weathering. Where the preliminary weathering is neglected and the wheat lands are not broken up till late, the crop is almost invariably uneven in texture. The preliminary weathering seems to lead to a uniform absorption of monsoon or irrigation water and to prevent local excess or defect of soil moisture. A uniform condition as regards soil moisture is naturally bound up with an even supply of moisture to the crop and this seems to be one of the causes of grain of even texture.